characteristic of rays of either end of the spectrum. The bean crop is harvested principally in the autumn, which brings the maximum amount of sunshine this region receives during any season of the year. The crop is sun-cured, and the dried beans are separated from the pods by means of thrashing.

Partly because of differences in the amounts of sunshine received, sugar beets grown for seed are cultivated in one region, while those grown for the beets are produced by another portion of the State. (Previous to 1915 most of the sugar-beet seed was imported from Germany.) Vegetables are grown in commercial quantities principally in the humid valleys bordering the coast. A very large crop of potatoes is grown in the delta district near the mouth of the Sacramento River. In this restricted region summer temperatures are not so high as in the more interior valleys, and evaporation is relatively small. Sunshine is reduced in amount, and of a peculiar quality adapted for vegetable growth.

The growing of flower and vegetable seeds is an important part of California agriculture. A considerable proportion of the flower and vegetable seeds of the United States is grown in this State. For some particular varieties, practically all of the seed produced in the United States comes from California. In general, much sunshine and a minimum of atmospheric moisture are the conditions best suited for seed production. These conditions are particularly desired during the summer harvest season, when the crops are sun cured, and the seeds are extracted by means of thrashing machinery.

That the people of California are not unmindful of the significance of sunshine as a resource is evident from the great frequency with which the word sun enters into their vocabulary. In this "Sunshine State" we have "Sunkist Oranges," "Sun-Maid Raisins," and "Sun-Sweet Prunes." Most of these are shipped eastward over the "Sunset Route." As it is recognized that sunshine is the best natural germicide, enterprising real estate dealers advertise "Sunlit Homes." Life is largely in the open. In southern California many people practically live out of doors and are known as "Sun-Worshipers." Both in attracting tourists and in aiding agriculture, sunshine is one of California's most valuable natural resources.

PROJECT FOR LOCAL FORECAST STUDIES.[1]

By R. H. WEIGHTMAN, Meteorologist.

Weather not only affects persons in all walks of life, but is a controlling influence in every phase of human endeavor. On the condition of the meteorological elements depends the convenience and success with which our daily tasks and pleasures are accomplished—from the child who is laying the foundation of his educational structure to the business and professional man engaged in the prosecution of useful pursuits. The fact that weather and its effects are of universal interest is as true to-day as in the past. As a natural and logical sequence to this universal and time-honored interest experienced by mankind as a whole, weather changes have been impressed on his attention, thus laying the foundation for the many dictums and proverbs, associated with nature's signs as revealed in the clouds, sunsets, the moon, and in the habits and actions of animals and plants that we have to-day. Some of these sayings have a more or less sound physical basis, while others are grounded in fancy and superstition. Nevertheless, they have been handed down from generation to generation without distinction, until they have gained an entirely false significance in the public mind, especially among those who have not had the occasion and inclination to actually compare the saying on the one hand with the occurrence of the meteorological phenomena on the other.

As the science of foretelling the weather has progressed, meteorologists have gradually discarded the consideration of local signs and influences as indices of subsequent weather in favor of the surer, sounder, and more accurate indications of the weather charts which depict simultaneous conditions over wide areas. In fact, they have gone so far in this direction that, at the present time, scant attention is paid to purely local conditions in the preparation of forecasts, although any one familiar with local signs must admit that, at times at least, they are exceedingly valuable and important.

In 1883 a treatise on "Weather Proverbs" was published by H. C. Dunwoody, and in 1903 Prof. Garriott presented his bulletin on "Weather Folk Lore and Local Weather Signs" which brought together many of these old dictums and sayings. Later, Prof. Humphreys, in an article entitled "Some Weather Proverbs and their Justification" which appeared in the May, 1911, issue of Popular Science Monthly gave some interesting and instructive views on the physical reasons and principles underlying some of them.

A table showing the probable character of the weather based on the barometric pressure and wind direction is given in the bulletin by Prof. Garriott, while in the MONTHLY WEATHER REVIEW numerous references to clouds as indicators of the subsequent occurrence of precipitation have appeared from time to time. Officials of the Weather Bureau have prepared tables showing the relation of temperature, humidity, wind direction, pressure, pressure change, clouds, etc., to subsequent weather but, from the fact that results obtained by these methods were not so reliable as those based on the daily weather charts, such schemes have not been widely appreciated, nor have they been very much used.

Although as a rule local conditions play a rather unimportant rôle in the preparation of the general forecasts, yet there are times when the results to be expected from the weather map are extremely uncertain and doubtful, and at such times the forecaster grasps at any indication that may give him a clue to what weather may be expected to follow. Only recently Maj. E. H. Bowie proposed that the relation or bearing of all the weather elements, or combinations of them, be brought together into a single index or probability number, the influence of the different elements being proportionally weighted and, provided such a plan prove feasible, that such information be included in the telegraphic report of observations. Such a scheme would be on a strictly statistical basis and would not involve in any way the personal equation of the observer. It has been contended that such a scheme has advantages in mountain and coastal regions but that it would not be suitable for use in level areas with continental climates where the local signs that might be considered as indications of local weather changes are merely the usual results of well-known meteorological laws. While the latter is true, it is patent that, as long as conditions undergo changes, the question is how far

[1] Read by title, American Meteorological Society, Washington, D. C., Apr. 22, 1920.

ahead are the incipient stages of these changes manifested in some one or more of the meteorological elements, whether it be in their absolute values, in the changes in them, or in a combination of the two. We know, for example, that changes from an entirely cloudless sky to a rain condition do not come about suddenly. There is some manifestation either in the amount of cloud, in a change in its type or height, in a change in pressure, in a shift in the wind, etc., and it is these preliminary signs that, it is believed, can be used to advantage for giving some clue to subsequent conditions. Of course, the shorter the interval between the time the forecast is made and the period covered by the forecast, the more certain will be the prediction but it seems reasonable that we may expect in many cases to find some indication at 8 a. m. for example of the incipient stage of the condition we may expect to occur between 8 p. m., and the succeeding 8 a. m. certainly at least the local conditions at 8 a. m. will give a valuable indication of the conditions to be expected in the succeeding 12 hours.

Attention has been given to the problem in Sweden by Bruno Rolf in a paper entitled "Probabilité et Prognostics des Pluies d'été" (Probability and forecasting of summer rains), published at Upsala in 1917, in which he shows the possibility of the development of such a system. He first arranges the data at Stockholm, covering a period of 59 years, by groups according to pressures, temperature departures, relative humidities, vapor pressures, directions of wind, cloudiness, and then by two and three element combinations, taking conditions at the 9 p. m. observation as the basis for prediction and comparing the indications with the precipitation that occurred during the 24 hours beginning at 8 a. m. of the succeeding day. Graphs are given showing the probability for each element and also for the two-element and three-element combinations. He shows that low pressure, low temperature, high relative humidity, high vapor pressure, and high values for cloudiness and the south wind are favorable for rain, while the opposite state of these elements and the west wind are unfavorable. For pressure, and combinations of pressure with other elements, the probability has the greatest values and the greatest range, and for vapor pressure, the least.

Although 59 years' observations were used, the author states that in dividing the material into groups according to the different values of three elements, the limit of possible division is reached for the reason that subdivision with regard to a fourth is too little provided with forms. Since it is found that the curves representing the probability of rain as a function of the pressure with different values of the other elements show more regularity and greater range within the limits of probability, 0 and 1, than curves giving the probability in terms of other arguments under different conditions of pressure, he overcomes the difficulty of further subdivision by developing a mathematical expression to represent this type of curves which he calls barombrometric curves, the terms of which are deduced from the data. This formula deals with the probability of rain based on three elements, pressure, cloudiness, and relative humidity, and the author states that other elements may be added by correcting or modifying the constants of the formula through the consideration of other factors. He considers only the state of the different elements, but believes that the scheme can be improved by considering also their changes. He has verified the operation of his scheme and finds that 44 per cent of the changes—whether from fair to rain, or rain to fair—are correctly forecast, while a verification of 80 per cent was obtained when conditions did not change, giving a combined percentage for all cases of 68 per cent. By considering the wind direction in addition, this verification was increased to 69 per cent. The author concludes as follows:

> The method of prediction, the application of which we have attempted, although it has led to appreciable results, has not yet been sufficiently elaborated in detail that one may affirm that it could be substituted for the synoptic charts. But *a priori* nothing opposes such an assertion. * * * In any case it can be affirmed that we have furnished a useful complement to the synoptic charts. * * * The salient point here is the simultaneous consideration of several elements; the attempts made thus far in taking account of only one have not, it must be admitted, led to very satisfactory results.

Another interesting paper by Geo. F. McEwen and Ellis L. Michael entitled "The functional relation of one variable to each of a number of correlated variables determined by a method of successive approximations to group averages," has been published recently in this country, and while it does not treat our problem directly, may possibly be susceptible of adaptation to it. The method of multiple or partial correlation has also been considered. The problem is a decidedly complex and difficult one for the reason that each, if not all, of the independent variables, namely, the different meteorological elements, will have quite different probability values depending on the values of the other elements and these relations, it is believed, will not be linear. It would seem, therefore, that they will have to be considered in combinations and the different values of these combinations of two or more elements will have to be introduced into the expression giving the form of the functional relation, much the same as was done by Rolf.

It is believed that a study of this character based on local indications is more applicable to short-range predictions (less than 12 hours, for instance), which are of such importance in connection with aviation work; and that results thus obtained will be sufficiently valuable to warrant the telegraphing of probability indices or numbers with the regular observations, as has been advocated by Maj. Bowie. However, the matter is still in the investigational stage and it is premature to come to any definite conclusions at this time.

It would seem, however, that a profitable, and in the United States at least, a rather unexplored field of investigation is open to local officials of the Weather Bureau in studying local data available at the time of the morning observation with a view to answering some of the numerous inquiries made by the public concerning weather conditions for the afternoon or evening, as for example: "Will it be cloudy this afternoon?" "Will it rain before noon?" "Will there be a thunderstorm?" "Will the snowfall be heavy or light?" etc., *ad infinitum*.

Considerable work has been done in the prediction of minimum temperatures from hygrometric observations by Prof. J. Warren Smith and others, some work has been done at the New York Weather Bureau office on heavy snowfalls, and undoubtedly considerable other work of a similar character, which has not come to the attention of the writer, has been carried out by other officials of the Bureau.

The methods of statistics afford a direct and efficient means of attacking the problem of making short-range predictions, a careful investigation of which will materially aid in stimulating and promoting the development of a more complete knowledge of the physical changes and processes that control atmospheric phenomena.